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United States
Department of
Agriculture
**Forest
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Southwestern
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Forest Pest Management Report

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WESTERN SPRUCE BUDWORM DAMAGE
ASSESSMENT PROJECT, 1980

Progress Report No. 3

April 1981

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WESTERN SPRUCE BUDWORM ASSESSMENT PROJECT

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by

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I. INTRODUCTION

The western spruce budworm, Choristoneura occidentalis Freeman, is a major defoliator of Douglas-fir (Pseudotsuga menziesii) and true fir (Abies spp.) in the western United States. During outbreaks of this insect, repeated defoliation of host trees causes growth loss, top-kill, and tree mortality. Faced with potentially serious tree damages, a forest manager must decide if pest management is warranted and, if it is, determine what methods are preferred. The manager must select a method that will be effective, economical, and environmentally acceptable, as well as compatible with management objectives. In order to make these decisions, the manager must have reliable damage information.

In the Southwest, little information has been collected on tree losses caused by the budworm; thus, a long-term damage assessment project was initiated in 1978. This report summarizes the methods used to assess tree damages and the results of sampling for 1978 through 1980.

II. OBJECTIVES

The purpose of this evaluation is to assess damages to Douglas-fir, true fir, and spruce caused by the western spruce budworm on the Carson National Forest, New Mexico. Specific objectives of the evaluation follow:

A. Growth Loss

1. Determine the amount of growth loss and recovery for past infestations that occurred from 1922-1966, and the current infestation which began in 1975.

2. Estimate densities of larvae and egg masses and relate these population indexes to tree defoliation and subsequent growth loss.

3. Determine if differences in growth loss and recovery occur among various site classes and timber-size classes.

4. Determine if defoliation and growth loss can be correlated by site classes and timber-size classes.

B. Top-kill and Tree Mortality

1. Determine the annual amount of top-kill and tree mortality caused by the current budworm infestation.

2. Estimate densities of larvae and egg masses and relate these population indexes to tree defoliation and subsequent top-kill and mortality.

3. Determine if defoliation and subsequent top-kill and mortality can be correlated by site classes and timber-size classes.

III. OUTBREAK HISTORY

The evaluation areas are located on the Taos, Questa, and Tres Piedras Ranger Districts of the Carson National Forest (Fig. 1, Appendix). Several infestation cycles of budworm have occurred on this Forest since records were first kept in the early 1920's. On the western part of the Carson, including the Tres Piedras District, an outbreak occurred from approximately 1922 to 1935. Then in the early 1940's, and again during the 1950's, widespread infestations occurred on the Tres Piedras, Taos, and Questa Ranger Districts. Infested areas on the Tres Piedras were sprayed with DDT in 1955. Another budworm outbreak occurred in the 1960's and portions of the following units were treated with DDT: Taos Ranger District, 1962; Tres Piedras, 1963; and Taos and Questa Ranger Districts, 1966. No visible defoliation was documented on the Tres Piedras Ranger District after 1963. The infestation remained in untreated portions of the Taos and Questa Ranger Districts until 1968, and then collapsed.

The current infestation was detected in 1975 when 520 acres of defoliation were observed in the Rio Pueblo de Taos watershed, Taos Pueblo Indian Reservation. The infestation increased manyfold in 1976 on the Reservation and the adjoining Carson National Forest. An aerial survey of the Taos and Questa Ranger Districts in 1978 revealed over 15,000 acres of defoliation (classified as light to heavy); and in 1979, over 30,500 acres. In 1980, over 62,500 acres were defoliated on the Taos and Questa Ranger Districts, plus about 550 acres on the Tres Piedras Ranger District. (Including adjacent Indian and private land, total area defoliated in 1980 was over 107,000 acres.) Egg mass data indicate the outbreak will continue to increase in size and intensity in 1981.

IV. METHODS

A. Block Establishment

Twelve, 1-acre blocks were permanently established in June 1978: nine blocks were located in drainages of the Rio Fernando de Taos on the Taos Ranger District (Capulin Canyon, Garcia Park, La Jara Canyon, and Palo Flechato Pass) and three blocks in the Cabresto Creek drainage on the Questa Ranger District (Figs. 2-6, Appendix). None of the blocks were located in the initial outbreak area where defoliation was detected in 1975. Little or no defoliation had occurred on these blocks prior to their establishment. First aerial detection of defoliation in the vicinity of the blocks was as follows: Capulin Canyon and Garcia Park, 1976; La Jara Canyon, Palo Flechato Pass, and Cabresto Canyon (blocks 11 and 12), 1977; and Cabresto Canyon (block 9), 1978.

In 1979, five additional blocks were established to serve as check blocks: four blocks (Nos. 13-16) near Osha Mountain on the Taos Ranger District and one block (No. 17) near Burned Mountain on the

Tres Piedras Ranger District (Figs. 7 and 8, Appendix). However, budworm populations were found on blocks 13-16 in 1979, and on block 17 in 1980. Defoliation on these blocks has not been detected in aerial surveys.

Dwarf mistletoe is widespread in Douglas-fir stands on the Carson National Forest and causes tree damages similar to those resulting from budworm defoliation. For this reason, an attempt was made to establish the first 12 damage assessment blocks in stands with little or no mistletoe; otherwise, it would be difficult to analyze damages due to budworm. However, half of block 7 is heavily infected with dwarf mistletoe. Also, in 1979, block 14 was deliberately established in a stand heavily infected with dwarf mistletoe. Data from these two areas may indicate whether or not heavier tree damages result when mistletoe and budworm are both present.

All blocks were permanently marked using paint and flagging, witness trees, and corner stakes. Blocks were located to provide a representative sample of three site classes and the past infestations. Three Douglas-fir site trees were measured on each block to determine site index. Site class codes were determined from site index values as follows:

Site Class Code	
I	site index 75 or above
II	site index 55-74
III	site index 54 or below

When each block was initially established, all trees (including nonhost species) with a d.b.h. of 5 inches or greater were permanently tagged with block and tree numbers. Trees with a d.b.h. of 5.0 to 8.9 inches were classed as poles, while those with a d.b.h. of 9.0 inches or larger were classed as sawtimber. The following information was obtained from each tree:

1. Species
2. Height (to nearest foot)
3. D.b.h. (to nearest 0.1 inch)
4. Amount of top-kill (length to nearest foot)
5. Condition (live or dead)
6. Crown ratio

On each block, a subsample of nine, 1/100-acre circular fixed plots were established to assess budworm damage to regeneration-size trees. Plot centers were located on a 90-foot grid in each block (Fig. 9, Appendix). All trees less than 5 inches in d.b.h. were examined and the following information recorded:

1. Species
2. D.b.h. (to nearest 0.1 inch)
3. Height (to nearest inch)
4. Visual estimate of defoliation (light, medium, or heavy)
5. Condition (live or dead)

Trees were classed as seedlings if d.b.h. was less than 0.5 inches and as saplings if d.b.h. was 0.5 to 4.9 inches.

B. Damage Assessment

1. Defoliation

On each block, 25 Douglas-fir trees, 20-40 feet in height, were selected for sampling defoliation in 1978 through 1983. To reduce the effect of sampling on individual trees, only 10 of the 25 were to be sampled each year (i.e., 1978, trees 1-10; 1979, trees 11-20; 1980, trees 21-25 and 1-5; etc.). Two methods were used to estimate defoliation:

a. Visual Method.[1/] Each sample tree was divided into three crown levels: upper, middle, and lower. Using binoculars, two observers made independent visual estimates of the percent defoliation of each crown level. These estimates were tallied by recording the midpoint value of the defoliation class in which each estimate belonged. The defoliation classes and midpoint values were as follows:

Defoliation class %	Midpoint value %
0-10	5
11-25	18
26-50	38
51-75	63
76-90	83
91-100	95

1/ Carolin, V. M., and W. K. Coulter. 1972. Sampling populations of western spruce budworm and predicting defoliation on Douglas-fir in eastern Oregon. USDA Forest Serv. Res. Pap. PNW-149. 39 pp.

The two midpoint values for a crown level were averaged and the resultant figure weighted using the following values: lower crown - 5, middle crown - 3, and upper crown - 1. The average midpoint value multiplied by the assigned weight gave the average defoliation of the crown level.

The sum of the three weighed averages was then divided by nine to give percent defoliation for the entire tree.

b. 6-class System.[2/] This method involved sampling four apical branches: a branch (70 cm in length) from each quadrant at midcrown of each sample tree. On each branch sample, 25 new shoots were examined for current defoliation using the left side of one branch and the right side of another, and so on. Each new shoot was individually examined for defoliation and assigned an index and midpoint value as follows:

Defoliation class %	Index value	Midpoint value
0	0	0
1-25	1	12.5
26-50	2	37.5
51-75	3	62.5
76-99	4	87.5
100	5	100

After index values were determined for the branch samples, individual tree defoliation was calculated using the following formula:

$$\% \text{ defoliation} = \frac{(n_1)(12.5) + (n_2)(37.5) + (n_3)(62.5) + (n_4)(87.5) + (n_5)(100)}{100}$$

Where n_1 = number of twiglets with index value 1
n_2 = number of twiglets with index value 2
n_3 = number of twiglets with index value 3
n_4 = number of twiglets with index value 4
n_5 = number of twiglets with index value 5

2/ Parker, D. L., R. E. Acciavatti, and E. D. Lessard. 1978. Western spruce budworm suppression and evaluation project using carbaryl, 1977. Progress Rep. No. 1, USDA Forest Serv., Southwestern Reg. 136 pp.

In both the visual method and the 6-class system, block defoliation was simply the average of the individual tree values.

2. Growth Loss

Core samples were taken from host trees in an attempt to measure radial growth loss and recovery for past infestations which occurred on the Carson National Forest from 1922 to 1966. Nonhost trees were sampled to determine expected growth of host trees and to help identify periods of growth loss due to other factors, such as drought.

On each block, two core samples per tree were taken from 30 sample trees: 10 Douglas-fir, 10 true fir, and 10 ponderosa pine. The core samples were placed in plastic straws for storage and labeled with plot number, tree number, and species. Radial growth measurements were done on an Addo System by the Intermountain Forest and Range Experiment Station, Moscow, Idaho.

Core samples will be taken during the final year of the project to determine when the current infestation began to affect radial growth and by what amount. The samples will also be analyzed to see if differences in growth reduction occurred between stands with different site classes and timber-size classes.

3. Top-kill and Tree Mortality

a. Poles and Sawtimber

Top-kill and tree mortality were recorded on all blocks. Both the incidence and amount of top-kill were measured. The length of the dead top, to the nearest foot, was estimated. All top-kill and tree mortality not attributed to the present infestation were recorded as old, and will be used as a base line for future damage assessment. All top-kill and tree mortality due to the present infestation were recorded each year.

Because trees have the ability to establish adventitious buds and refoliate after intense defoliation, it is sometimes difficult to determine top-kill from a single observation. Therefore, when top-kill was observed on a tree for the first time, it was classified as "apparent" top-kill. Then if top-kill was observed on the same tree the following year, it was classified as "confirmed" top-kill.

In 1980, 14 of the blocks were examined by a pathologist to determine if any pathogens were present which could produce or contribute to the occurrence of top-kill and mortality. In addition, after tree conditions are recorded each year, dead and dying trees will be thoroughly examined to determine if pathogens contributed to or caused death.

b. Seedlings and Saplings

The condition of seedlings and saplings was checked annually. Data were recorded on tree mortality, top-kill, and defoliation (low, moderate, or heavy).

C. Insect Densities

On each block, 25 Douglas-fir trees, 20-40 feet in height, were selected for sampling insect densities. To reduce the effect of sampling on individual trees, only 10 of the 25 were to be sampled each year (i.e., 1978, trees 1-10; 1979, 11-20; 1980, 21-25 and 1-5; etc.). These sample trees were the same as those selected for defoliation sampling.

1. Larvae

Sampling was begun when 20 percent of the larvae were in the fifth instar or larger. On each tree, two 15-inch branches were cut from opposite sides of the midcrown using a pole pruner with attached collecting bag. If a sample branch did not have at least 15 live buds, another branch was cut. The length and width of branches were recorded to determine the foliated branch surface area.

Larvae were removed from sample branches, counted, and preserved in ethyl alcohol. Total numbers of larvae and live buds per branch were recorded. Vials containing the larvae were labeled with block and tree numbers and the collection date. Head capsule measurements were taken on a 25 percent subsample from each vial to determine instar distribution at time of sampling.

2. Egg Masses

Egg masses were sampled by cutting two 70 cm midcrown branches from opposite sides of each sample tree with a pole pruner. The length and width of branches were measured to calculate foliated branch surface area. Each branch was then individually bagged in a 1/4-bushel paper or cloth sack, transported to the laboratory, and stored at about 40° F prior to examination.

Foliage was examined under ultraviolet light for egg masses. Needles bearing egg masses were classed as from current year's foliage or a previous year's and kept separate in labeled pill boxes. New egg masses, deposited in the year of sampling, were separated under a stereomicroscope from old egg masses deposited in the previous year(s). All egg masses on current year's foliage were classed as new and their characteristics formed the basis for aging those egg masses found on a previous year's foliage.

V. RESULTS

A. Block Establishment

Seventeen blocks were established: blocks 1 through 12 in 1978, and blocks 13 through 17 in 1979. The productivity of a site to grow Douglas-fir (site index) was used as the primary criterion for block selection (Table 1, Appendix).

When each block was established, all trees 5 inches in diameter and larger were examined and their species, size, and condition recorded in order to form a basis to determine future effects resulting from the current outbreak. With the exception of block 5, which had about 60 percent ponderosa pine, host species for the budworm were most abundant. Densities of trees ranged from 66 to 327 trees per acre. Refer to Table 2, Appendix, for species diversity and stocking density data.

For trees less than 5 inches in diameter, the total number of trees on nine, 1/100-acre plots ranged from 63 to 330 trees, which converts to 699 to 3,508 trees per acre (Table 3, Appendix). Host trees comprised about 76 to 100 percent of all trees, and white fir generally was the predominant species.

B. Damage Assessment

1. Defoliation

Defoliation estimates for pole- and sawtimber-sized Douglas-fir in 1978 through 1980 are shown in Table 4, Appendix. On blocks 1 through 12, where 3 years of data have been collected, the overall average defoliation increased from 1978 to 1979 and then stayed at the same level in 1980: 6-class system, 53, 82, and 83 percent; visual method, 41, 80, and 80 percent. Average defoliation on blocks 13 through 16 (which became infested with budworm in 1979) increased from 1979 to 1980: 6-class system, 8 to 26 percent; visual method, 5 to 8 percent.

Block 17 became infested with budworm in 1980. Visual defoliation remained at 5 percent in 1979 and 1980 (remember, a 5 percent rating represents 0-10 percent defoliation); while the 6-class defoliation index increased: 0 percent in 1979 to 26 percent in 1980.

After several years, an analysis will be made to determine the intensity of defoliation required to cause top-kill and tree mortality. The total defoliation over time will be used as the measure of defoliation intensity. That is, if a particular tree has been top-killed by budworm after 3 years of continuous defoliation--30 percent in year 1, 50 percent in year 2, and 90 percent in year 3--the defoliation intensity will be recorded as 170 percent. It may be that a particular sequence of yearly defoliation will cause top-kill. As an example, 30, 50, and 90 percent annual defoliation may cause top-

kill, but 90, 50, and 30 percent may not cause top-kill. Both would have the same defoliation intensity--170 percent. Therefore, both defoliation intensity and sequence of defoliation will be examined.

2. Growth Loss

Increment cores were measured to determine the effect of budworm defoliation on radial growth. Measurements of the cores taken in 1978 (blocks 1-12) and 1979 (blocks 13-17) are being analyzed. An attempt will be made to analyze the effects of past infestations on the different site classes and timber size-classes, and present these data in a later report.

3. Top-kill and Tree Mortality

Loss assessment data for budworm have never been collected in the Southwest, especially on a yearly basis, and the current data indicate that tree damages and losses may be heavier than anticipated. Permanent tree damages began to appear in 1978--3 years after visible defoliation occurred on the Forest--and increased in 1979 and 1980. In the following discussion, confirmed top-kill and tree mortality figures are always cumulative, that is, 1980 mortality would include trees killed in 1978, 1979, and 1980.

a. Poles and Sawtimber

Examination of top-kill data for poles and sawtimber (Tables 5 and 6, Appendix) shows damage increased each year. The average apparent top-kill for pole-sized trees on blocks 1 through 12 was 4.6, 28.4, and 54.4 percent for 1978, 1979, and 1980, respectively. Average confirmed top-kill for the same trees increased from 1.2 percent in 1978 to 11.7 percent in 1979. Confirmed top-kill represents the minimum amount of damage which occurred and probably underestimates the actual amount of top-kill. For sawtimber-sized trees on blocks 1 through 12, apparent top-kill in 1978, 1979, and 1980 averaged 4.6, 16.2, and 34.9 percent, respectively; and confirmed top-kill for 1978 and 1979 averaged 2.8 and 6.5 percent, respectively.

Only a small amount of top-kill occurred on blocks 13 through 16, which first became infested with budworm in 1979. The average apparent top-kill increased from 1979 to 1980: on poles, 0.3 to 5.5 percent; and on sawtimber, 0.3 to 1.8 percent. No top-kill occurred on block 17 where budworm first appeared in 1980.

No mortality of pole- or sawtimber-sized trees was found in 1978 (Tables 7 and 8, Appendix). Average mortality for blocks 1 through 12 was 0.3 percent for poles and 0.2 percent for sawtimber in both 1979 and 1980. On the blocks established in 1979, no mortality occurred except for one tree on block 16 in 1980.

Examination of the blocks revealed the presence of several pathogens which cause tree mortality regardless of the presence of budworm (Table 9). A total of eight pole- and sawtimber-sized

trees died on the 17 blocks: Garcia Park (block 2), one pole-sized tree in 1980 and (block 7), one pole-sized tree in 1979; La Jara Canyon (block 3), one pole-sized tree and three sawtimber-sized trees in 1979; Palo Flechato Pass (block 1), one sawtimber-sized tree in 1979; and Osha Mountain (block 16), one pole-sized tree in 1980. Spruce budworm defoliation was probably not the primary cause of death for most, if not all, of these trees. For example, the four dead trees in La Jara Canyon were wind-thrown. Two of the trees were Douglas-firs; the other two were spruce, whose roots had been weakened by Inonotus tomentosus root rot. Another example--even though no pathogens were found on block 16, it is highly improbable that budworm was a primary cause of mortality. Budworm defoliation had been too light: with a block average of 1.4 and 1.8 percent (6-class) in 1979 and 1980, respectively. However, in Garcia Park, the additional stress of budworm defoliation probably hastened the death of trees already affected by root rot or dwarf mistletoe. The only case in which budworm may have been the direct cause of tree mortality was on block 1, where no pathogen was found and where tree defoliation averaged above 85 percent for both 1979 and 1980.

b. Seedlings and Saplings

On blocks 1 through 12, no top-kill of seedlings and saplings was found in 1978 and mortality was at very low levels--average of 0.2 percent, seedlings, and 0.5 percent, saplings (Tables 10 and 11, Appendix). In 1979, apparent top-kill averaged 2.7 and 6.3 percent for seedlings and saplings, respectively, while confirmed top-kill averaged 2.2 and 5.1 percent. Apparent top-kill increased dramatically in 1980: 23.5 percent for seedlings and 35.1 percent for saplings. Average mortality increased slightly each year: 0.8 and 0.5 percent in 1979 for seedlings and saplings, respectively, and 2.1 and 0.8 percent in 1980.

The greatest amount of seedling mortality occurred on block 8, near Palo Flechato Pass: 0.5, 3.3, and 8.4 percent in 1978, 1979, and 1980, respectively. Block 8 is heavily infected with Armillaria mellea and Fomitopsis annosa (=Fomes annosus), and these root rots were probably the primary cause of death. Most of the dead seedlings had been young, vigorous trees, 2 to 5 feet in height; most were adjacent to other dead seedlings. Some of the seedlings had been heavily defoliated in the year or two prior to death, and, in those cases, mortality probably resulted from a combination of budworm defoliation and root rot.

On the more recently infested Osha Mountain blocks (Nos. 13-16), no seedling or sapling mortality has yet occurred. Average apparent top-kill of seedlings increased from 1.4 percent in 1979 to 4.8 percent in 1980, while that of saplings decreased slightly from 2.2 to 2.1 percent. However, confirmed top-kill in 1979 averaged only 0.7 percent for seedlings and none for saplings. Budworm was first observed on these blocks in 1979, and apparently defoliation has not yet had permanent impact on the regeneration-sized trees.

On the Burned Mountain block, no. 17, no mortality of seedlings and saplings occurred. Apparent top-kill was 10.8 percent on seedlings in both 1979 and 1980, and 7.7 and 3.9 percent on saplings in 1979 and 1980, respectively. However, there was no confirmed top-kill on seedlings in 1979 and only 3.9 percent on saplings.

C. Insect Densities

Larval and egg mass density data show that the infestation has been at a relatively high level on some blocks for 3 years, and egg mass data indicate the infestation is increasing on most blocks (Table 12, Appendix).

For blocks 1 through 12, larval densities averaged 25.4 larvae per 100 buds in 1979 and 16.5 larvae in 1980. These figures indicate a down trend; however, egg mass, defoliation, and top-kill data disagree. One fact was observed which suggests that the larval sample could have been underestimated. On all the blocks which had densities of 20 or more larvae per 100 buds in 1979, larval counts appeared to decrease in 1980. However, on these same blocks a tremendous amount of adventitious budding occurred in 1980. There were several times the number of buds on the same branch area in 1980 as were recorded in 1979. This may have lowered the larval count when the numbers of larvae collected were converted to a per 100 bud density.

Larval densities on blocks 13 through 16 increased from 0.4 larvae per 100 buds in 1979 to 4.8 larvae in 1980. Block 17 on the Tres Piedras Ranger District became infested in 1980 with 0.8 larvae per 100 buds.

The average egg mass density for blocks 1 through 12 increased each year from 1978 to 1980: 20.6, 37.8, and 58.6 egg masses per m^2. On the Osha Mountain blocks, the average density increased from 11.3 in 1979 to 16.4 egg masses per m^2 in 1980. At Burned Mountain, where no egg masses were found in 1979, 1.8 egg masses per m^2 were counted in 1980. Average densities per block in 1980 ranged from 1.8 to 92.7 egg masses per m^2. Densities on individual trees were as high as 205.9 egg masses per m^2 of foliage.

VI. PLANS FOR F.Y. 1981

Data will continue to be collected on defoliation, tree damages and losses, and insect densities.

A P P E N D I X

Table 1.--Douglas-fir site index and class for 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.

Ranger District	Location	Block	Site index	Site class
Taos	Capulin Canyon	5	80	I
		6	50	III
Taos	Garcia Park	2	50	III
		7	60	II
		10	60	II
Taos	La Jara Canyon	3	70	II
		4	80	I
Taos	Palo Flechato Pass	1	50	III
		8	70	II
Questa	Cabresto Canyon	9	80	I
		11	90	I
		12	80	I
Taos	Osha Mountain	13	70	II
		14	60	II
		15	60	II
		16	80	I
Tres Piedras	Burned Mountain	17	60	II

Table 2.--Species composition in year of block establishment for trees 5 inches in d.b.h. or greater, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.

Location	Block	Stocking density								Total no. trees/acre
		Douglas-fir		True fir		Spruce		Pine		
		No.	%	No.	%	No.	%	No.	%	
Capulin Canyon	5	21	29.2	8	11.1	0	.0	43	59.7	72
	6	29	43.9	20	30.3	0	.0	17	25.8	66
Garcia Park	2	202	87.8	15	6.5	1	0.5	12	5.2	230
	7	209	82.9	6	2.4	0	.0	37	14.7	252
	10	83	50.0	20	12.1	2	1.2	61	36.7	166
La Jara Canyon	3	46	44.2	13	12.5	44	42.3	1	1.0	104
	4	76	63.9	5	4.2	37	31.1	1	0.8	119
Palo Flechato Pass	1	120	62.5	62	32.3	8	4.2	2	1.0	192
	8	119	71.7	18	10.8	1	0.6	28	16.9	166
Cabresto Canyon	9	94	70.1	4	3.0	0	.0	36	26.9	134
	11	85	66.4	20	15.9	22	17.2	1	0.8	128
	12	112	65.1	10	5.8	49	28.5	1	0.6	172
Osha Mountain	13	152	93.3	8	4.9	3	1.8	0	.0	163
	14	85	45.2	51	27.1	5	2.7	47	25.0	188
	15	111	62.7	14	7.9	52	29.4	0	.0	177
	16	40	12.2	54	16.5	233	71.3	0	.0	327
Burned Mountain	17	167	81.9	15	7.3	22	10.8	0	.0	204

Table 3.--Species composition in year of block establishment for trees less than 5 inches in d.b.h., Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.[1/]

Location	Block	Stocking density								Total no. trees/acre
		Douglas-fir		True fir		Spruce		Pine		
		No.	%	No.	%	No.	%	No.	%	
Capulin Canyon	5	288	23.0	666	53.1	0	.0	300	23.9	1,254
	6	255	20.2	1,010	79.8	0	.0	0	.0	1,265
Garcia Park	2	355	32.0	755	68.0	0	.0	0	.0	1,110
	7	522	72.3	167	23.1	0	.0	33	4.6	722
	10	388	40.2	422	43.7	34	3.5	122	12.6	966
La Jara Canyon	3	233	22.8	311	30.4	444	43.5	33	3.3	1,021
	4	544	62.0	100	11.4	200	22.8	33	3.8	877
Palo Flechato Pass	1	1,199	37.0	1,909	58.9	133	4.1	0	.0	3,241
	8	511	14.6	2,964	84.5	22	0.6	11	0.3	3,508
Cabresto Canyon	9	1,243	84.2	211	14.3	0	.0	22	1.5	1,476
	11	433	12.7	2,464	72.3	500	14.7	11	0.3	3,408
	12	1,010	38.6	1,010	38.6	577	22.0	22	0.8	2,619
Osha Mountain	13	211	24.7	633	74.0	11	1.3	0	.0	855
	14	444	34.2	722	55.6	111	8.5	22	1.7	1,299
	15	178	25.4	377	54.0	144	20.6	0	.0	699
	16	89	3.6	2,053	82.6	344	13.8	0	.0	2,486
Burned Mountain	17	167	22.7	544	74.3	22	3.0	0	.0	733

1/ Based on nine, 1/100-acre plots per block. Blocks 1-12 were established in 1978; blocks 13-17 in 1979.

Table 4.--Percent Douglas-fir defoliation on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.

Location	Block	Percent defoliation[a]					
		1978[b]		1979		1980	
		6-class	Visual	6-class	Visual	6-class	Visual
Capulin Canyon	5	65.6	54.2	93.4	93.5	79.9	74.7
	6	22.0	28.8	60.2	56.1	80.9	84.2
Garcia Park	2	47.0	33.7	80.2	72.6	80.8	68.5
	7	54.6	35.9	89.6	89.9	79.0	61.7
	10	70.2	43.4	90.6	93.0	82.6	80.4
La Jara Canyon	3	64.8	50.7	86.0	89.0	79.5	93.1
	4	69.1	63.4	86.9	84.6	77.6	87.8
Palo Flechato Pass	1	47.5	40.3	88.1	94.7	85.7	78.1
	8	66.5	48.9	93.1	91.4	84.0	80.2
Cabresto Canyon	9	11.7	6.0	29.1	5.0	66.0	58.6
	11	60.7	51.7	95.2	94.3	99.5	95.0
	12	50.7	35.3	94.7	95.0	99.6	95.0
Average (1-12)		52.5	41.0	82.3	79.9	82.9	79.8
Osha Mountain[c]	13	---	---	12.7	5.0	45.9	15.1
	14	---	---	9.7	5.0	36.1	6.1
	15	---	---	7.5	5.0	20.4	5.0
	16	---	---	1.4	5.0	1.8	5.0
Average (13-16)		---	---	7.8	5.0	26.1	7.8
Burned Mountain[d]	17	---	---	0.0	5.0	25.7	5.0

a/ Each block percentage is the average defoliation of 10 single-tree samples.
b/ Blocks 13-17 were established in 1979.
c/ Budworm first observed in 1979.
d/ Budworm first observed in 1980.

Table 5.--Top-killed pole-sized host trees[a/] on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.[b/]

Location	Block	Total no. host trees	Old top-kill[c/]		New top-kill							
					No. of trees			Apparent (%)			Confirmed (%)[d/]	
			No.	%	1978	1979	1980	1978	1979	1980	1978	1979
Capulin Canyon	5	5	0	.0	1	2	3	20.0	40.0	60.0	.0	.0
	6	25	1	4.0	7	8	12	28.0	32.0	48.0	12.0	20.0
Garcia Park	2	138	4	2.9	0	16	73	.0	11.6	52.9	.0	3.6
	7	142	2	1.4	0	16	70	.0	11.3	49.3	.0	7.0
	10	74	7	9.5	2	14	36	2.7	18.9	48.6	.0	.0
La Jara Canyon	3	43	3	7.0	0	7	35	.0	16.3	81.4	.0	2.3
	4	58	1	1.7	1	41	47	1.7	70.7	81.0	1.7	41.4
Palo Flechato Pass	1	140	2	1.4	1	60	73	0.7	42.9	52.1	0.7	21.4
	8	66	5	7.6	0	17	29	.0	25.8	43.9	.0	13.6
Cabresto Canyon	9	63	1	1.6	1	0	11	1.6	.0	17.5	.0	.0
	11	84	2	2.4	0	45	68	.0	53.6	81.0	.0	31.0
	12	122	1	0.8	0	22	46	.0	18.0	37.7	.0	.0
Average	1-12	80.0	2.4	3.4	1.1	20.7	41.9	4.6	28.4	54.4	1.2	11.7
Osha Mountain	13	117	0	.0	---	0	20	---	.0	17.1	---	.0
	14	80	11	13.8	---	1	4	---	1.3	5.0	---	.0
	15	87	3	3.4	---	0	0	---	.0	.0	---	.0
	16	263	5	1.9	---	0	0	---	.0	.0	---	.0
Average	13-16	136.8	4.8	4.8	---	0.3	6.0	---	0.3	5.5	---	.0
Burned Mountain	17	106	3	2.8	---	0	0	---	.0	.0	---	.0

a/ Douglas-fir, true fir, and spruce, 5.0-8.9 inches d.b.h.
b/ Blocks 1-12 established 1978; blocks 13-17, 1979. Blocks 13-16 became infested 1979; block 17, 1980.
c/ Top-kill prior to and not attributable to current budworm infestation.
d/ Percent of total number host trees with top-kill which was verified the following year. (Figures are cumulative).

Table 6.--Top-killed sawtimber-sized host trees[a/] on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.[b/]

Location	Block	Total no. host trees	Old top-kill[c/]		New top-kill							
					No. of trees			Apparent (%)			Confirmed (%)[d/]	
			No.	%	1978	1979	1980	1978	1979	1980	1978	1979
Capulin Canyon	5	24	0	.0	6	9	12	25.0	37.5	50.0	16.7	20.8
	6	24	0	.0	7	6	11	29.2	25.0	45.8	16.7	20.8
Garcia Park	2	80	2	2.5	0	22	32	.0	27.5	40.0	.0	2.5
	7	73	0	.0	0	3	11	.0	4.1	15.1	.0	.0
	10	31	3	9.7	0	3	8	.0	9.7	25.8	.0	.0
La Jara Canyon	3	60	0	.0	0	4	27	.0	6.7	45.0	.0	3.3
	4	60	0	.0	0	13	23	.0	21.7	38.3	.0	10.0
Palo Flechato Pass	1	50	3	6.0	0	6	9	.0	12.0	18.0	.0	2.0
	8	72	2	2.8	1	15	31	1.4	20.8	43.1	.0	6.9
Cabresto Canyon	9	35	0	.0	0	0	4	.0	.0	11.4	.0	.0
	11	43	0	.0	0	12	32	.0	27.9	74.4	.0	11.6
	12	49	1	2.0	0	1	6	.0	2.0	12.2	.0	.0
Average	1-12	50.1	0.9	1.9	1.2	7.8	17.2	4.6	16.2	34.9	2.8	6.5
Osha Mountain	13	46	0	.0	---	0	2	---	.0	4.3	---	.0
	14	61	6	9.8	---	0	1	---	.0	1.6	---	.0
	15	90	2	2.2	---	1	1	---	1.1	1.1	---	1.1
	16	64	1	1.6	---	0	0	---	.0	.0	---	.0
Average	13-16	65.3	2.3	3.4	---	0.3	1.0	---	0.3	1.8	---	0.3
Burned Mountain	17	98	0	.0	---	0	0	---	.0	.0	---	.0

a/ Douglas-fir, true fir, and spruce, 9 inches d.b.h. or greater.
b/ Blocks 1-12 established 1978; blocks 13-17, 1979. Blocks 13-16 became infested 1979; block 17, 1980.
c/ Top-kill prior to and not attributable to current budworm infestation.
d/ Percent of total number host trees with top-kill which was verified the following year. (Figures are cumulative).

Table 7.--Mortality of pole-sized host trees[a/] on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-1980.[b/]

Location	Block	Total no. host trees	Mortality [c/]					
			No. of trees			Percent		
			1978	1979	1980	1978	1979	1980
Capulin Canyon	5	5	0	0	0	.0	.0	.0
	6	25	0	0	0	.0	.0	.0
Garcia Park	2	138	0	0	1	.0	.0	0.7
	7	142	0	1	1	.0	0.7	0.7
	10	74	0	0	0	.0	.0	.0
La Jara Canyon	3	43	0	1	1	.0	2.3	2.3
	4	58	0	0	0	.0	.0	.0
Palo Flechato Pass	1	140	0	0	0	.0	.0	.0
	8	66	0	0	0	.0	.0	.0
Cabresto Canyon	9	63	0	0	0	.0	.0	.0
	11	84	0	0	0	.0	.0	.0
	12	122	0	0	0	.0	.0	.0
Average	1-12	80.0	.0	0.2	0.3	.0	0.3	0.3
Osha Mountain	13	117	--	0	0	--	.0	.0
	14	80	--	0	0	--	.0	.0
	15	87	--	0	0	--	.0	.0
	16	263	--	0	1	--	.0	0.4
Average	13-16	136.8	--	.0	.3	--	.0	.1
Burned Mountain	17	106	--	0	0	--	.0	.0

a/ Douglas-fir, true firs, and spruce, 5.0-8.9 inches d.b.h.
b/ Blocks 1-12 established 1978; blocks 13-17, 1979. Blocks 13-16 became infested 1979; block 17, 1980.
c/ Figures are cumulative.

Table 8.--Mortality of sawtimber-sized host trees [a] on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80. [b]

Location	Block	Total no. host trees	Mortality [c]					
			No. of trees			Percent		
			1978	1979	1980	1978	1979	1980
Capulin Canyon	5	24	0	0	0	.0	.0	.0
	6	24	0	0	0	.0	.0	.0
Garcia Park	2	80	0	0	0	.0	.0	.0
	7	73	0	0	0	.0	.0	.0
	10	31	0	0	0	.0	.0	.0
La Jara Canyon	3	60	0	3	3	.0	0.5	0.5
	4	60	0	0	0	.0	.0	.0
Palo Flechato Pass	1	50	0	1	1	.0	2.0	2.0
	8	72	0	0	0	.0	.0	.0
Cabresto Canyon	9	35	0	0	0	.0	.0	.0
	11	43	0	0	0	.0	.0	.0
	12	49	0	0	0	.0	.0	.0
Average	1-12	50.1	.0	0.3	0.3	.0	0.2	0.2
Osha Mountain	13	46	--	0	0	--	.0	.0
	14	61	--	0	0	--	.0	.0
	15	90	--	0	0	--	.0	.0
	16	64	--	0	0	--	.0	.0
Average	13-16	65.3	--	.0	.0	--	.0	.0
Burned Mountain	17	98	--	0	0	--	.0	.0

a/ Douglas-fir, true firs, and spruce, 9 inches d.b.h. or greater.
b/ Blocks 1-12 established 1978; blocks 13-17, 1979. Blocks 13-16 became infested 1979; block 17, 1980.
c/ Figures are cumulative.

Table 9.--Disease conditions on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-1980.

Location	Block	Disease conditions [1/]
Capulin Canyon	5	No discernable disease.
	6	Slight broom rust, TF. Severe dwarf mistletoe, PP. *Armillariella mellea* (=*Armillaria mellea*) and *Fomitopsis annosa* (=*Fomes annosus*), PP.
Garcia Park	2	*Phaeolus schweinitzii* (=*Polyporus schweinitzii*, DF.
	7	Severe dwarf mistletoe, DF, on half of block. *A. mellea* present.
	10	*A. mellea* present.
La Jara Canyon	3	*Inonotus tomentosus* (=*Polyporus tomentosus*), (=*Polyporus circinatus*), SP.
	4	Not examined.
Palo Flechato Pass	1	No discernable disease.
	8	*A. mellea* and *F. annosa*; at least 1/4 of block infected.
Cabresto Canyon	9	Not examined.
	11	No discernable disease.
	12	No discernable disease.
Osha Mountain	13	*A. mellea* present.
	14	Severe dwarf mistletoe, DF. *A. mellea* and *F. annosa* present.
	15	*A. mellea* present.
	16	No discernable disease.
Burned Mountain	17	Not examined.

1/ *A. mellea* and *F. annosa* affects DF, TF, and SP.
P. schweinitzii affects DF.
I. tomentosus affects SP.
DF = Douglas-fir; TF = true fir; SP = spruce.

Table 10.--Top-kill and mortality of host-tree seedlings[a/], Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-1980.[b/]

Location	Block	Total no. seedlings/ acre[c/]	Percent trees affected							
			Apparent top-kill			Confirmed top-kill[d/]		Mortality[d/]		
			1978	1979	1980	1978	1979	1978	1979	1980
Capulin Canyon	5	588	.0	1.9	20.8	.0	1.9	.0	.0	.0
	6	577	.0	9.6	17.3	.0	9.6	1.9	1.9	3.9
Garcia Park	2	810	.0	1.4	42.5	.0	1.4	.0	.0	.0
	7	178	.0	.0	50.0	.0	.0	.0	.0	.0
	10	366	.0	3.0	33.3	.0	3.0	.0	.0	.0
La Jara Canyon	3	422	.0	.0	13.2	.0	.0	.0	.0	2.6
	4	511	.0	.0	17.4	.0	.0	.0	.0	2.2
Palo Flechato Pass	1	1,832	.0	10.3	31.5	.0	9.1	.0	2.4	5.5
	8	2,375	.0	1.4	7.5	.0	1.4	0.5	3.3	8.4
Cabresto Canyon	9	966	.0	.0	13.8	.0	.0	.0	1.2	1.2
	11	999	.0	4.4	24.4	.0	.0	.0	1.1	1.1
	12	1,665	.0	0.7	10.7	.0	.0	.0	.0	0.7
Average	1-12	742.8	.0	2.7	23.5	.0	2.2	0.2	0.8	2.1
Osha Mountain	13	411	---	2.7	2.7	---	2.7	---	2.7	2.7
	14	588	---	1.9	11.3	---	.0	---	.0	3.8
	15	278	---	.0	4.0	---	.0	---	.0	.0
	16	1,010	---	1.1	1.1	---	.0	---	.0	1.1
Average	13-16	571.8	---	1.4	4.8	---	0.7	---	0.7	1.9
Burned Mountain	17	411	---	10.8	10.8	---	.0	---	.0	.0

a/ Includes Douglas-fir, true fir, and spruce trees with d.b.h. less than 0.5 inches and minimum height of 12 inches.

b/ Blocks 1-12 established 1978; 13-17 in 1979. Top-kill and mortality present year of plot establishment will be used as baseline data and will not be attributed to budworm.

c/ Based on total number of host-tree seedlings found on nine, 1/100-acre sample plots per block the year of block establishment.

d/ Figures are cumulative.

Table 11.--Top-kill and mortality of host-tree saplings[a/], Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-1980.[b/]

Location	Block	Total no. saplings/ acre[c/]	Percent trees affected							
			Apparent top-kill			Confirmed top-kill[d/]		Mortality[d/]		
			1978	1979	1980	1978	1979	1978	1979	1980
Capulin Canyon	5	78	.0	.0	57.1	.0	.0	.0	.0	.0
	6	555	.0	.0	8.0	.0	.0	.0	.0	.0
Garcia Park	2	178	.0	25.0	50.0	.0	25.0	.0	.0	.0
	7	466	.0	2.4	54.8	.0	.0	.0	.0	.0
	10	366	.0	6.1	45.5	.0	.0	.0	.0	3.0
La Jara Canyon	3	322	.0	.0	34.5	.0	.0	.0	.0	.0
	4	200	.0	11.1	33.0	.0	11.1	5.6	5.6	5.6
Palo Flechato Pass	1	1,254	.0	23.0	59.3	.0	20.4	.0	.0	.0
	8	444	.0	7.5	27.5	.0	5.0	.0	.0	.0
Cabresto Canyon	9	344	.0	.0	16.1	.0	.0	.0	.0	.0
	11	522	.0	.0	17.0	.0	.0	.0	.0	.0
	12	722	.0	.0	18.5	.0	.0	.0	.0	1.5
Average	1-12	454.3	.0	6.3	35.1	.0	5.1	0.5	0.5	0.8
Osha Mountain	13	311	---	.0	.0	---	.0	---	.0	.0
	14	422	---	.0	2.6	---	.0	---	.0	.0
	15	255	---	.0	.0	---	.0	---	.0	.0
	16	377	---	8.8	5.9	---	.0	---	.0	.0
Average	13-16	341.3	---	2.2	2.1	---	.0	---	.0	.0
Burned Mountain	17	289	---	7.7	3.9	---	3.9	---	.0	.0

a/ Includes Douglas-fir, true fir, and spruce trees with d.b.h. of 0.5-4.9 inches.
b/ Blocks 1-12 established 1978; 13-17 in 1979. Top-kill and mortality present year of plot establishment will be used as baseline data and will not be attributed to budworm.
c/ Based on total number of host-tree saplings found on nine, 1/100-acre sample plots per block the year of block establishment.
d/ Figures are cumulative.

Table 12.--Larval and egg mass densities[a/], Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80[b/].

Location	Block	Larvae/100 buds		Egg masses/m^2 of foliage		
		1979	1980	1978	1979	1980
Capulin Canyon	5	29.2	14.3	25.1	32.8	92.7
	6	15.9	19.6	13.1	36.6	89.6
Garcia Park	2	20.3	15.7	11.1	34.0	72.2
	7	29.2	13.6	27.3	47.6	39.3
	10	28.9	15.2	21.5	40.2	78.5
La Jara Canyon	3	26.8	14.6	17.0	39.5	31.8
	4	21.7	13.0	34.9	35.1	50.9
Palo Flechato Pass	1	36.6	19.6	41.1	25.2	66.8
	8	33.2	15.2	24.2	33.0	71.2
Cabresto Canyon	9	7.7	19.1	3.6	21.5	24.4
	11	28.9	22.9	15.2	67.9	42.5
	12	25.9	15.0	13.6	39.6	43.8
Average	1-12	25.4	16.5	20.6	37.8	58.6
Osha Mountain	13	0.8	12.9	---	25.4	32.0
	14	0.2	3.1	---	16.5	14.3
	15	0.3	1.9	---	.0	13.7
	16	0.1	1.5	---	3.3	5.4
Average	13-16	0.4	4.8	---	11.3	16.4
Burned Mountain	17	.0	0.8	---	.0	1.8

a/ On each block: average density for 10 Douglas-fir trees; 2 branches per tree.
b/ Blocks 1-12 established in 1978; 13-17 in 1979.

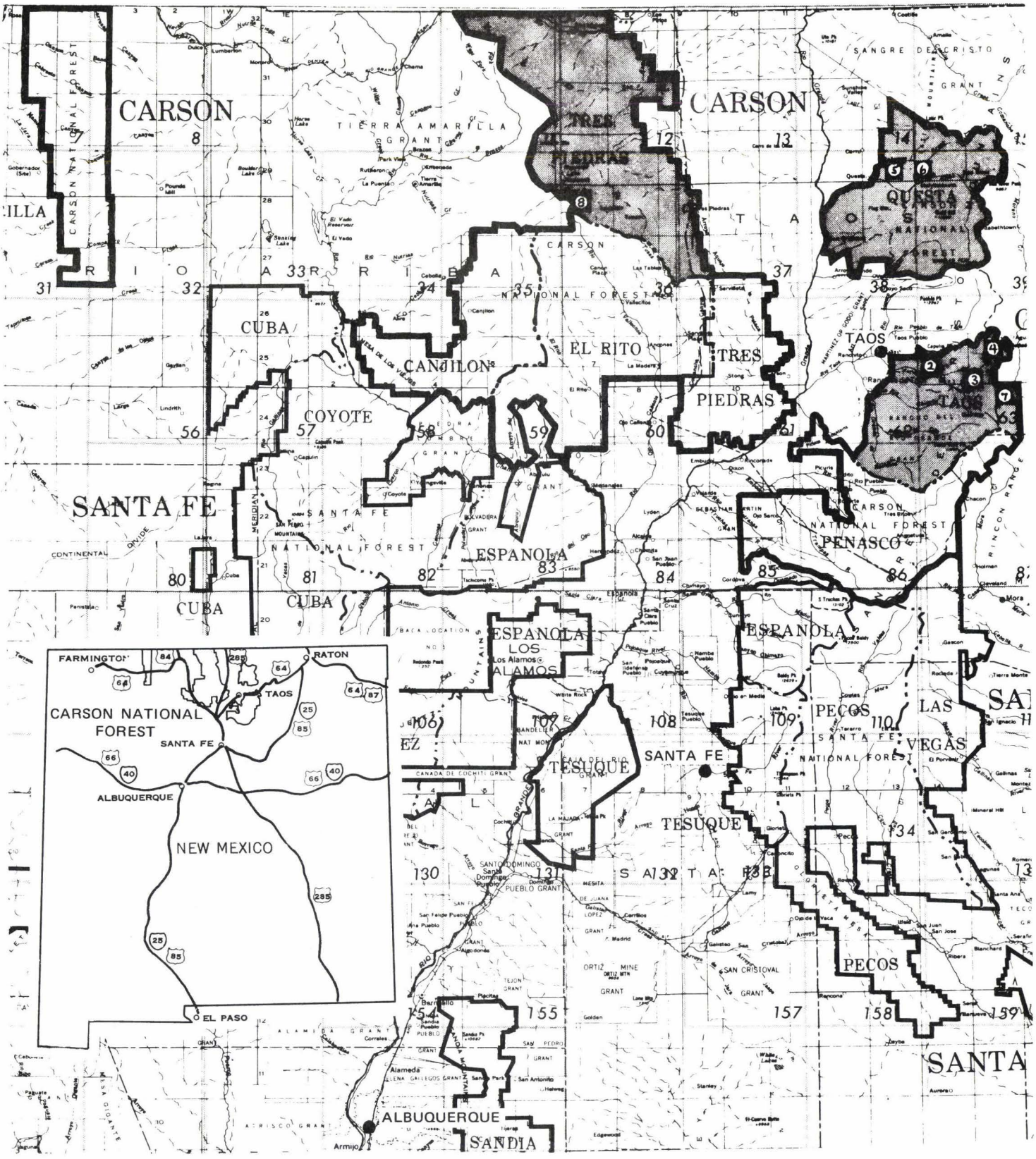

Figure 1. General location of evaluation blocks for the Spruce Budworm Damage Assessment Project on the Tres Piedras, Questa, and Taos Ranger Districts, Carson National Forest, 1978-80. Numbers (2 - 8) indicate subsequent maps (Figures 2-8) which show specific locations of 17 evaluation blocks.

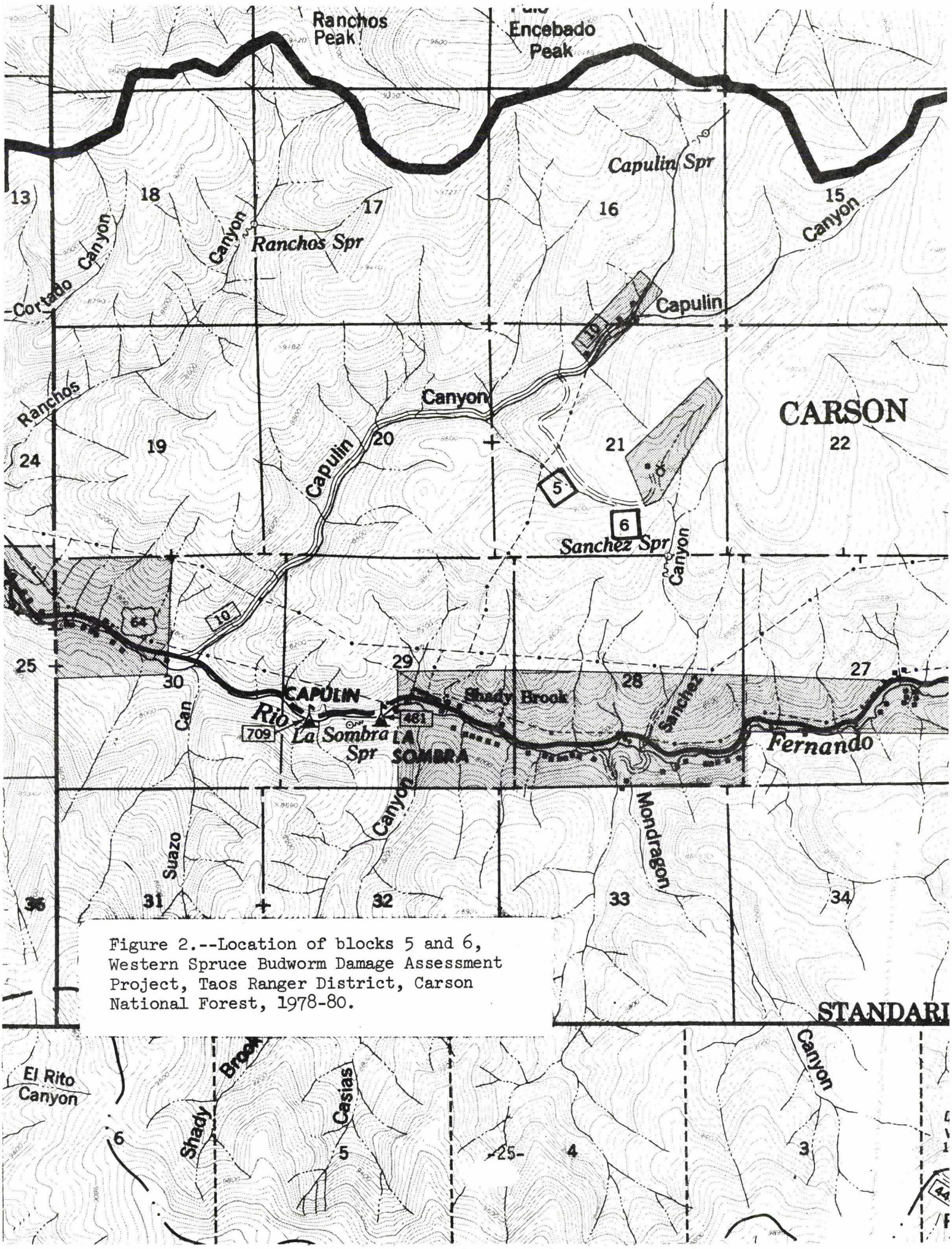

Figure 2.--Location of blocks 5 and 6, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1978-80.

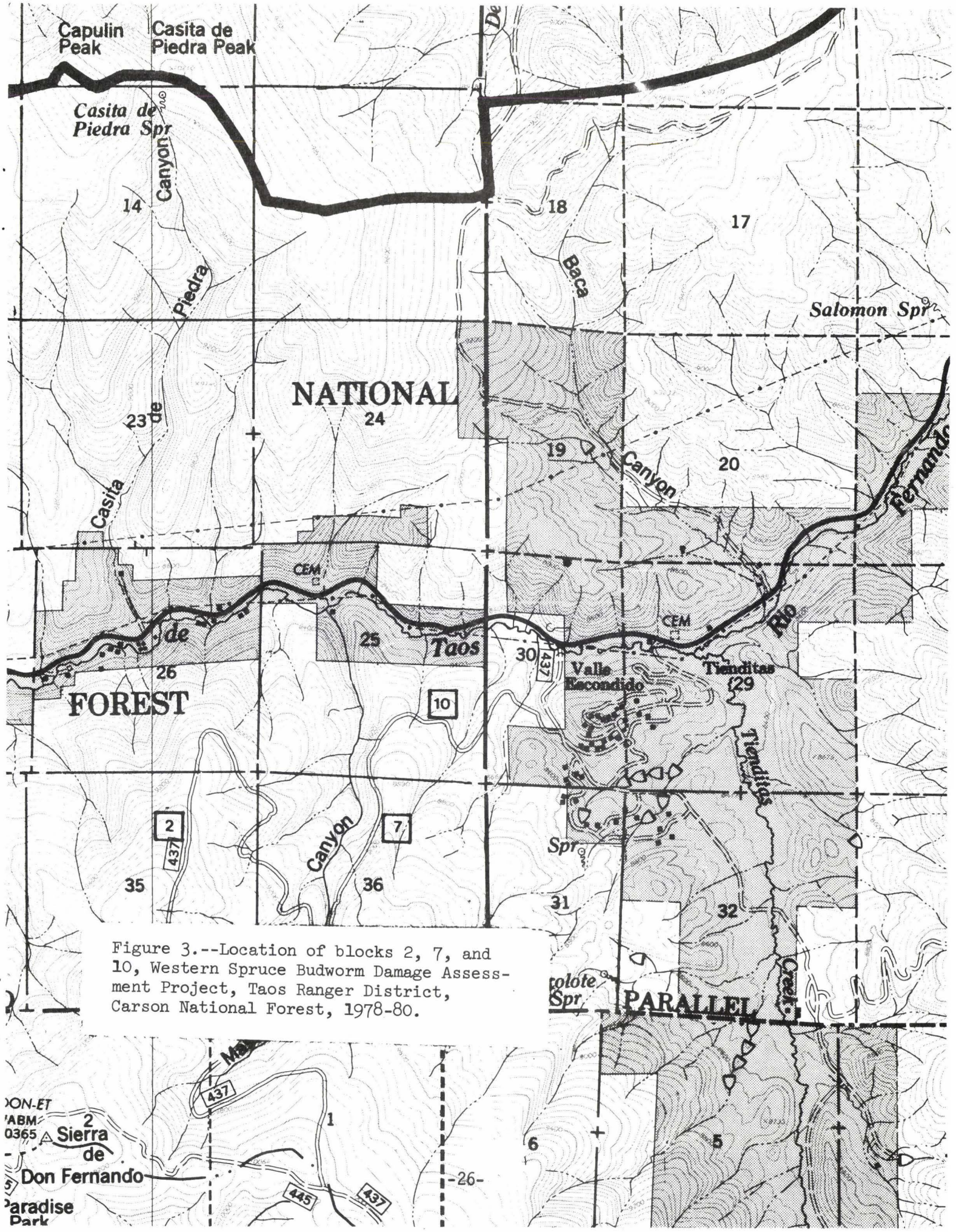

Figure 3.--Location of blocks 2, 7, and 10, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1978-80.

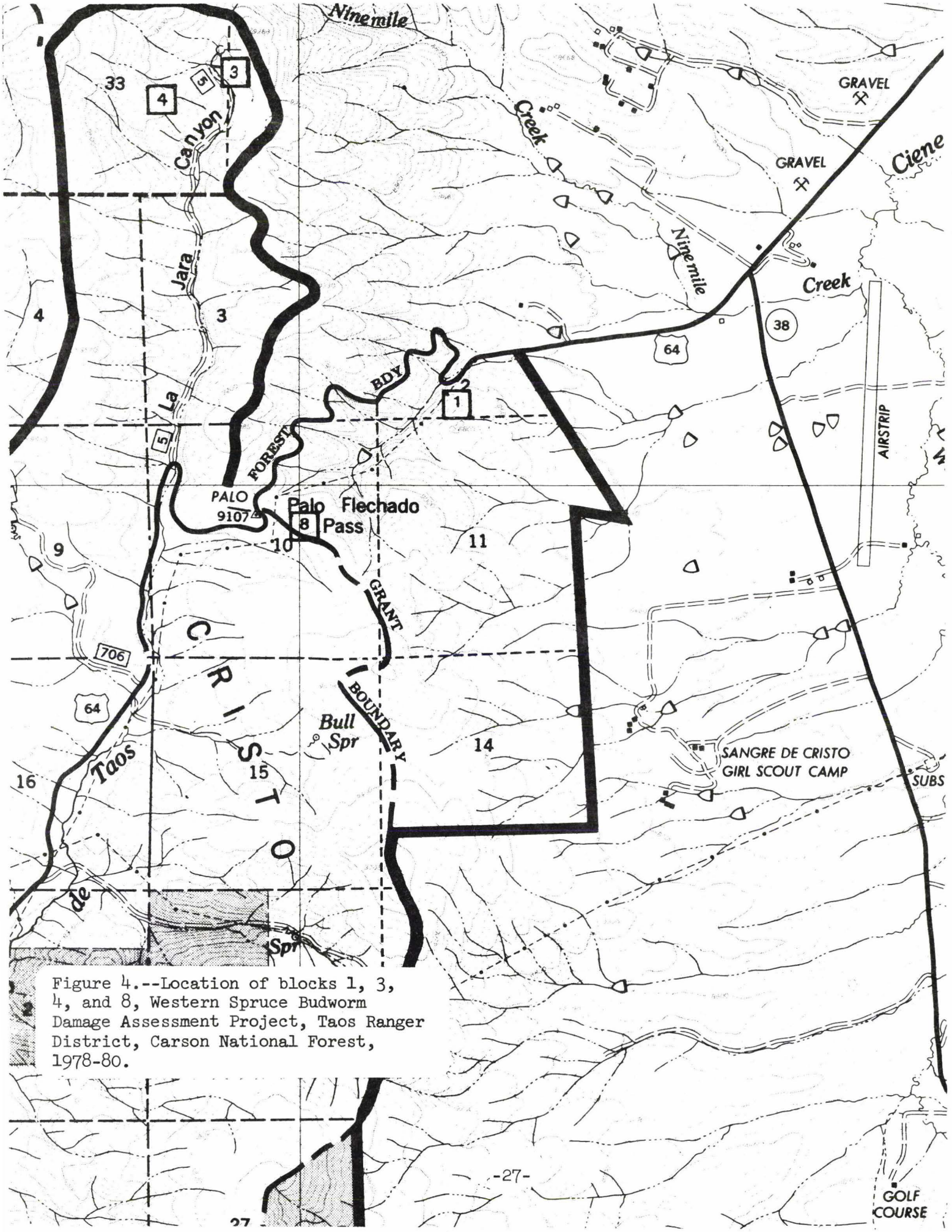

Figure 4.--Location of blocks 1, 3, 4, and 8, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1978-80.

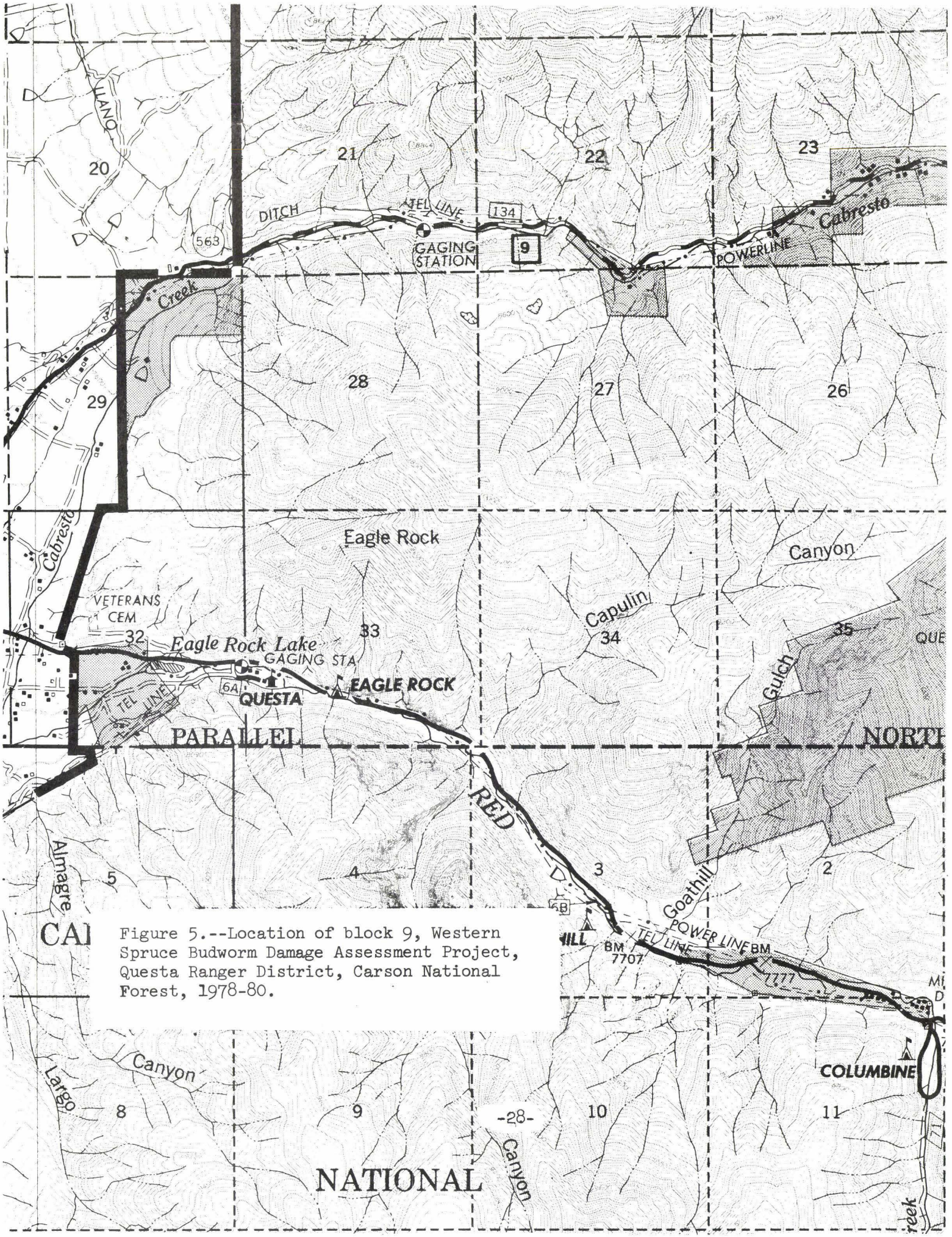

Figure 5.--Location of block 9, Western Spruce Budworm Damage Assessment Project, Questa Ranger District, Carson National Forest, 1978-80.

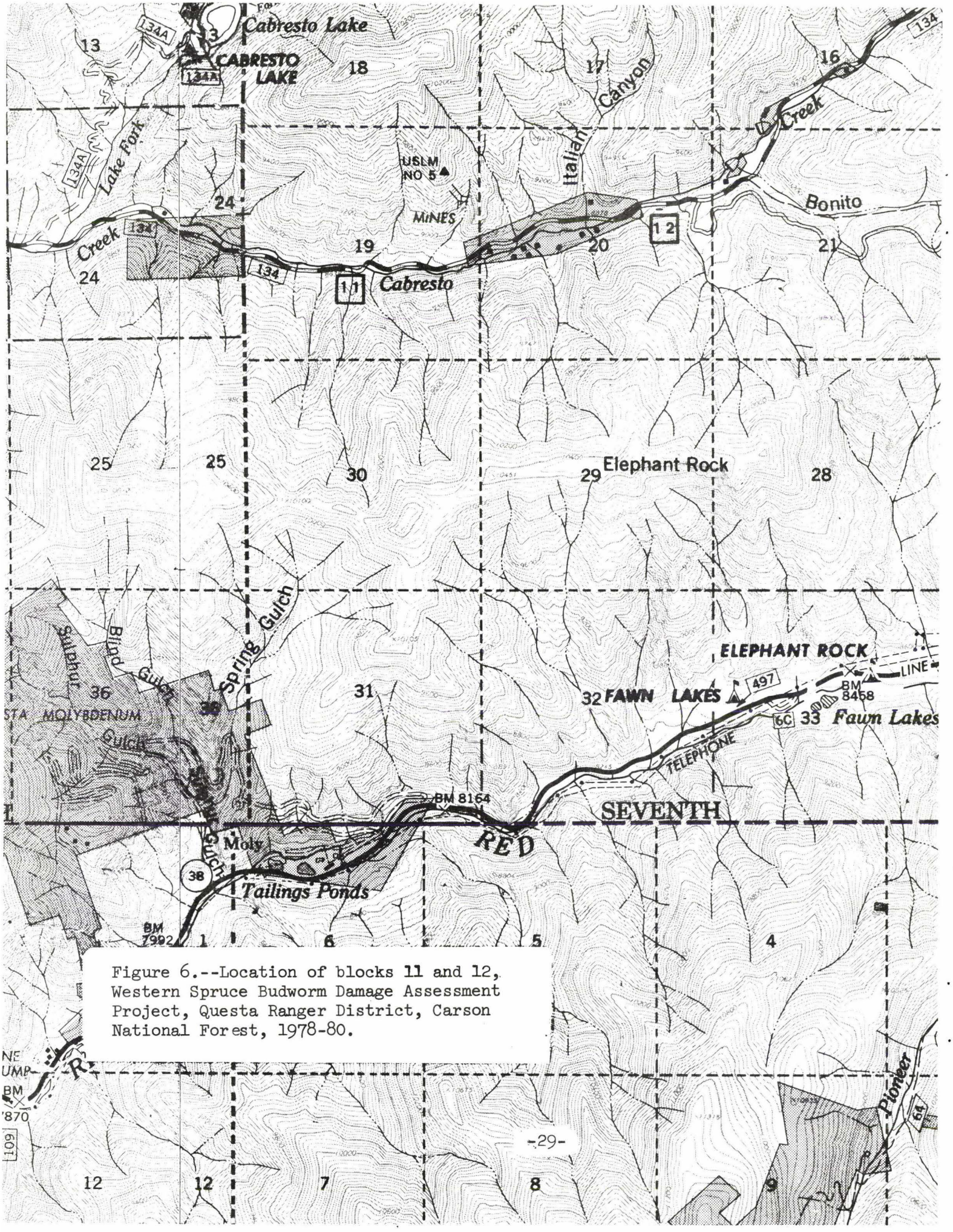

Figure 6.--Location of blocks 11 and 12, Western Spruce Budworm Damage Assessment Project, Questa Ranger District, Carson National Forest, 1978-80.

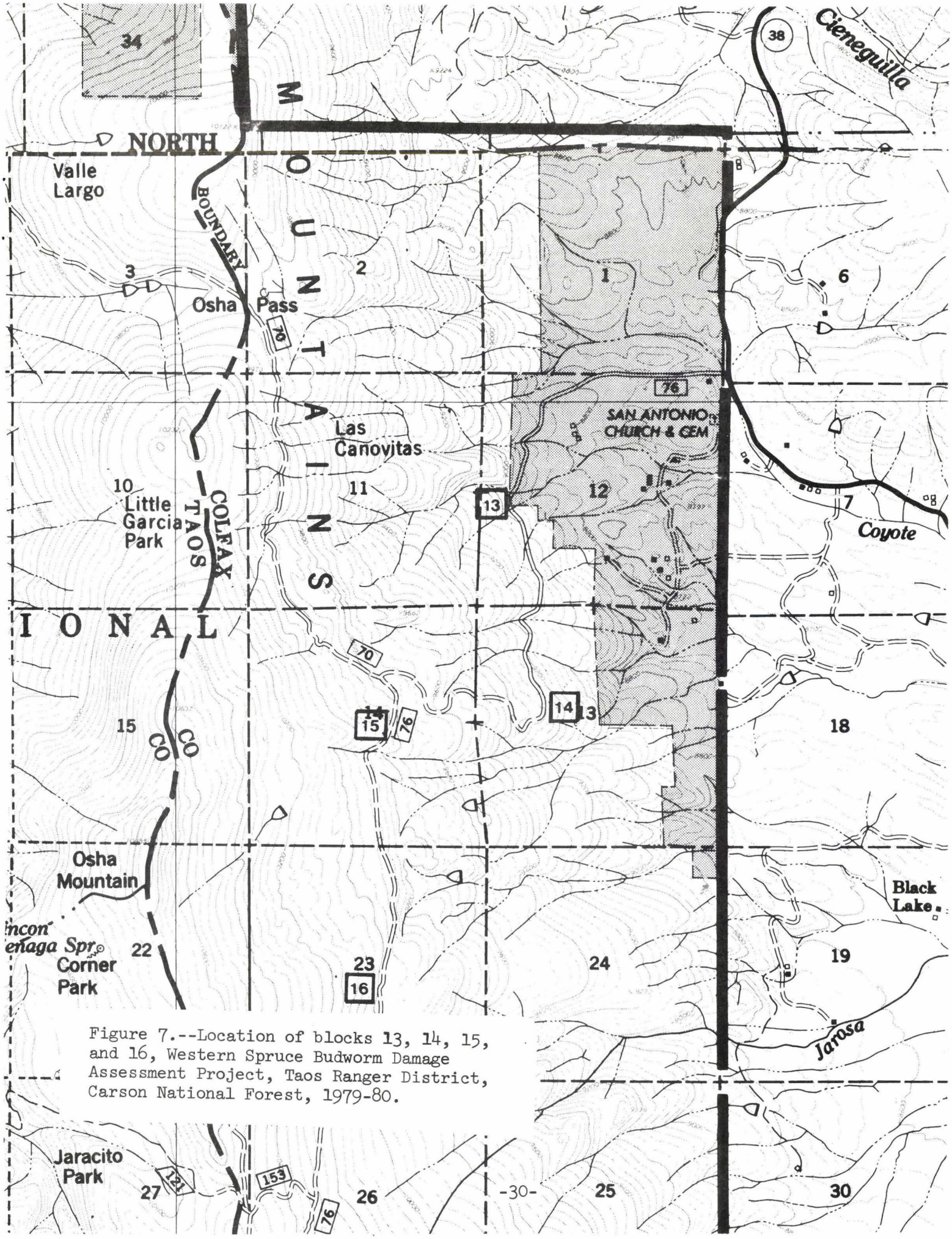

Figure 7.--Location of blocks 13, 14, 15, and 16, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1979-80.

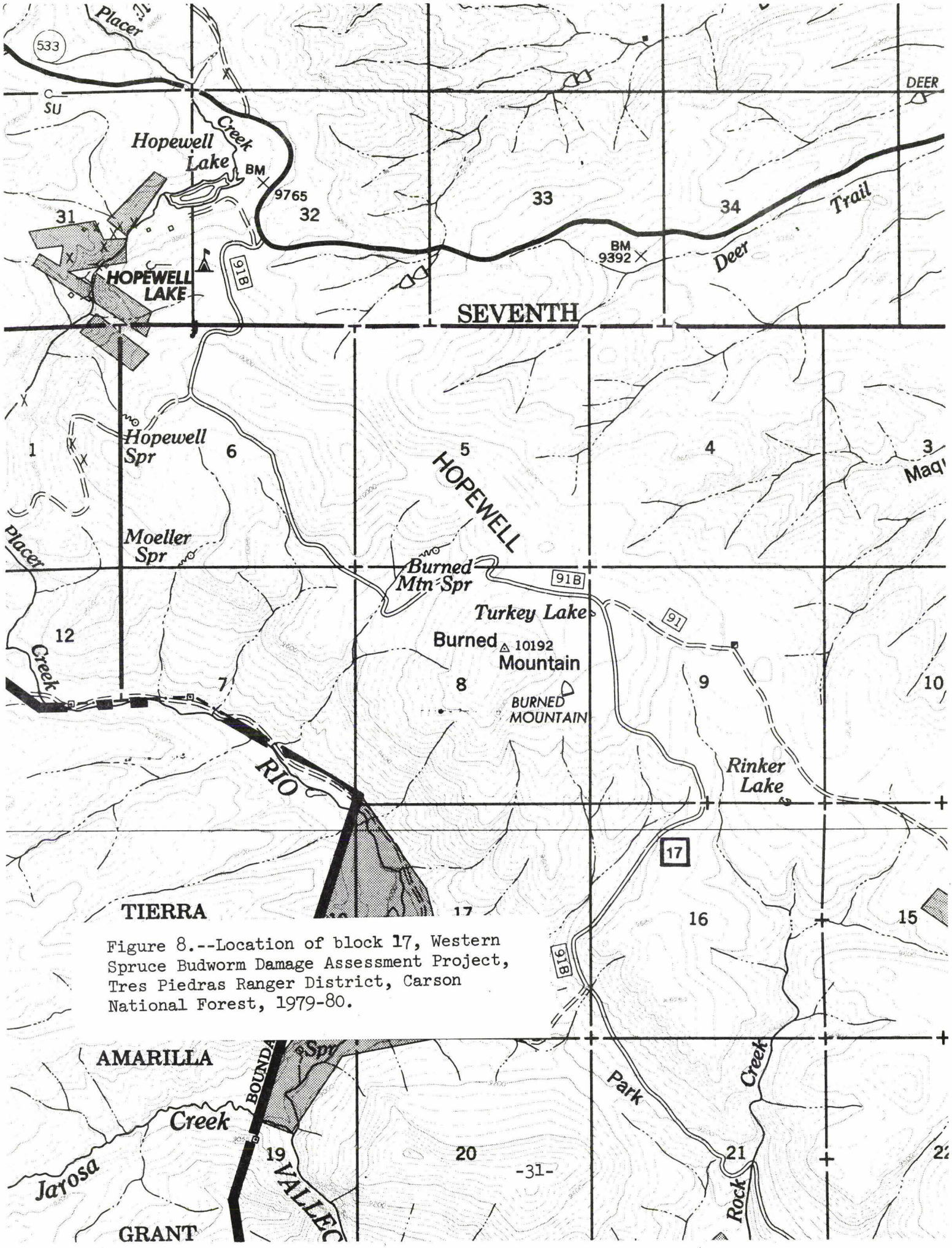

Figure 8.--Location of block 17, Western Spruce Budworm Damage Assessment Project, Tres Piedras Ranger District, Carson National Forest, 1979-80.

Figure 9.--Layout of 1/100-acre circular plots on 1-acre blocks, Western Spruce Budworm Damage Assessment Project, Carson National Forest, New Mexico, 1978-80.

Scale is 2" = 100'